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Use Rooting Hormones, or Not?
Multiple Applications May Be Best

Plant growers know when propagating plants from cuttings, rooting hormones are essential to produce quality roots. The question may come up, if one rooting hormone application is good, are two or more applications better?

Plant propagation from cuttings can be performed using rooting hormones by either basal or foliar methods. Basal methods use either dry power rooting hormones or rooting solutions. Foliar methods use aqueous IBA (K-IBA) rooting solutions on leafy cuttings in the growing state. Traditionally these methods have been used by one application.

Improving single rooting hormone application, secondary foliar applications may enhance the rooting of slow-to-root cuttings, and may level crops that have difference in growth. The first rooting hormone application, at time of sticking, may be performed by any foliar or basal method. Secondary applications are performed by spraying on leaves by the Spray Drip Down Method. Secondary applications are used on cuttings already in media; subsequent sprays do not disturb the cuttings. Secondary applications have been successful at ten days or two weeks after the first application. Also successful are three day applications in sequence directly after sticking.

Control (no treatment) | 600 ppm IBA (one treatment) ★ | 600 ppm IBA (two treatments) ★

Osteospermum (var sweet yellow) study by Dr. Allen Hammer,
Photos taken 21 days after sticking. Treatments: at sticking day and 10 days after sticking

Many factors must be considered to develop single or multiple rooting hormone applications.

- For plants propagated from cuttings, the cuttings must be taken from carefully maintained stock plants. Rooting hormone applications improve root formation on un-rooted (see the Ball study) and rooted cuttings. Juvenile cuttings root at lower rooting hormone rates as compared with mature cuttings (see the Ficus study). To select the optimal rooting hormone rates, trials must be made at low to high rates (see the Ficus and Osteospermum studies).
- The first rooting hormone application may be performed by any basal or foliar method. Secondary IBA rooting solution applications must be foliar by the Spray Drip Down Method using aqueous solutions made using Hortus IBA Water Soluble Salts. First and secondary foliar spray applications may be at the same rate (see rates, methods and products). There are positives to use secondary applications with no apparent negatives.
- When using secondary applications, herbaceous plant cuttings may perform better when using first application at time of sticking and secondary applications after ten days (see the Osteospermum study). Woody plant cuttings may perform better when using first application at time of sticking and secondary applications after two week intervals. Alternately, after sticking, application near the time of sticking and again on the second and third days after (see the Decker study).
- Secondary foliar applications on rooted cuttings may be used to level crops. Rooted transplants may benefit from foliar spray where root generation is stimulated.

Four studies are attached.

The first three studies used IBA rooting solutions made using Hortus IBA Water Soluble Salts

- "Use Rooting Hormone or Eat Ice Cream?" (Grower Talks) by Ball FloraPlant technical advisors, give reasons for using rooting hormones.
- An Osteospermum study, by Dr. P. Allen Hammer, shows how optimum IBA rooting solution rates are selected and the effect of two solution applications.
- Dr. Fred Davies study on Ficus pumila (based upon his thesis) describes the efficacy of foliar applied aqueous IBA rooting solutions on root formation concerning cutting maturity. It also discusses differences in root formation related to time-based applications.
- "Foliar Applied Rooting Hormones"(IPPS presentation), by Brian Decker, describes multiple foliar applications in woody plant propagation.

Some growers feel there is no need to use rooting hormones when propagating plants despite obtaining poor roots. They feel any roots are enough. Poor cutting roots result in poor plants. Applications of rooting hormones to the cuttings result in high quality uniform roots.

The Ball FloraPlant article says:

"Is it worth it? Please trial under your propagation conditions to check."

"So, in conclusion, if you want to root cuttings as fast as Rickey Henderson steals bases, you should use rooting hormone. I think that you should start a trial today-even on crops that don't require rooting hormone to see if you can root faster, high-quality liners.

Our conclusion was that IBA spray at 100 ppm [for the crops studied] gave the best rooting results while providing the lowest input cost during stick."

Ball FloraPlant scientists used IBA rooting solutions made with Hortus IBA Water Soluble Salts.

Dr. Hammer's Osteospermum herbaceous plant study was to find the optimum IBA rooting hormone rate and secondary spray timing. Trial IBA rooting solution rates were from low to very high. The photos taken on the 21st day after sticking show the rate and timing efficacy.

Application was by foliar applied aqueous IBA rooting solutions made with Hortus IBA Water Soluble Salts. The study compares:

- one application at time of sticking.
- one application at time of sticking, and a second application on the tenth day after sticking.

The first and supplementary applications were at the same rate. The untreated control cuttings had small roots. Trial treated cuttings showed variable roots related to the IBA rooting solution rates. For the crop studied, optimal roots were achieved when the cuttings were treated at time of sticking and also the tenth day, using a rooting solution rate of 600 *ppm* IBA.

Dr. Davies' Ficus pumila study used either one foliar aqueous IBA rooting solution application at time of sticking or one application several days after sticking. The study states:

> *"Adventitious root formation was stimulated with foliar application of indolebutyric acid (IBA)."* Dr. Davies' first step was to do *"an experiment to establish optimum IBA concentration required for rooting." "All growth regulators were applied as aqueous sprays."* Juvenile vs. mature cuttings,*"Lower IBA levels were required for optimal rooting in juvenile compared with mature LBC [leaf bud cuttings]."* For the crop studied, noticing rooting differences based upon type of cutting, *"Hormonal effects during rooting stages: Percentage rooting in IBA pretreated cuttings was unaffected by additional IBA at any of the 3 time intervals after insertion, however, root length was reduced in all treatments. In juvenile LBC receiving no treatment, later IBA applications increased rooting in all dates, but in mature cuttings only the first or second application period was stimulatory.*"

Brian Decker's studies involved the propagation of woody plant cuttings. The study states:

Spray Protocol for IBA Spray Application:

- *Use a Hortus IBA Water Soluble Salts solution.*
- *Use a flag marker to mark each days sticking progress to track the 3 day spray rotation.*
- *All Hormone applications occur in early morning. Stomata are open and cuttings are generally not in moisture stress.*
- *Improve root formation during positive trials at either when spraying three days in a row after sticking, or spraying at three times weekly after sticking.*

The first and daily secondary applications were at the same rate. Decker also used an alternate method, applying soon after sticking with a secondary application after about two weeks. These techniques gave cuttings stronger root mass compared with single treated cuttings. Extending Decker's results, later weekly applications may improve the roots of slow-to-root cuttings.

Discussion on optimum cuttings and use of rooting hormones by single or multiple application

The need for single or multiple rooting hormone applications is related to cutting quality. The best quality cuttings must be selected when propagating using rooting hormones. Juvenile cuttings are preferred. It is first necessary to determine the optimal rate by performing a block of trials on un-rooted cuttings using low to high rates (as seen in the Osteospermum study).

When performing rate trials on herbaceous cuttings from off shore plantations, as seen in the Osteospermum study, it is possible to determine relatively standard optimal rates. The rates may be specific to varieties but not necessarily suitable for the entire species. Woody cuttings have an additional variable as seen in the Ficus study. Juvenile cuttings taken early in the season, require lower rates than mature cuttings taken later in the season. Mature cuttings may not have as much reaction to application when applied later in the rooting cycle.

The strategy to perform multiple solution applications has merit. It needs to be tested on various plant varieties. To be determined, if a specific species or variety has low rooting ability then multiple applications may be less likely to be effective, or may be timing dependent. The results might not be the same within a variety, even by color variation.

Secondary rooting hormone application may be beneficial if after one application is it found cuttings are slow-to-root or have a low rooting percentage.

Trials must be made to compare a single application method with secondary applications. For secondary applications always use the foliar Spray Drip Down Method. For all applications the Spray Drip Down Method may be most effective and convenient.

To trial secondary applications, for herbaceous and woody plant cuttings first treat by any method, near or at the time of sticking. For secondary applications select either of these ways:

- First treat then repeat with sprays at about ten day to two week intervals.
- First treat then spray the cuttings two additional days in a row.

When transplanting young rooted plantlets to improve root generation and root mass:

- Rooted transplants, including grass divisions, may be treated both first and secondary by the foliar Spray Drip Down Method. Repeat spray in about two week intervals. Foliar rooting solution rates are similar to those used for initial rooting.

To answer the question, if one rooting hormone application is good, are two or more applications better? *It is worth trying!*

Rates, Methods and Products Used in Multiple Rooting Hormone Applications

K-IBA is the water soluble form of IBA.
Used here, "rooting solution" is a "rooting hormone" solution.

Dry Dip Products, Method, and Trial Rates

For the first IBA rooting hormone application, one option is by the Dry Dip Method using an IBA rooting hormone powder. Some cuttings root best using Dry Dip powders.

Rooting Hormone Powder Products

- **Rhizopon® AA #1** (0.1% IBA) for easy-to-root cuttings
- **Rhizopon® AA #2** (0.3% IBA) the intermediate all purpose rooting hormone for easy to more difficult-to-root cuttings.
- **Rhizopon® AA #3** (0.8% IBA) for more difficult-to-root cuttings

Dry Dip Method (only used for a first rooting hormone application)
The basal ends of the cuttings are dipped about 3/4 inch into the powder then stuck in media

Dry Dip Powder Trial Rates

- Annual plant cuttings: Rhizopon AA #1, or Rhizopon AA #2
- Perennial plant cuttings: Rhizopon AA #1, Rhizopon AA #2, or Rhizopon AA #3
- Woody plant cuttings: Rhizopon AA #2, or Rhizopon AA #3

Rooting Solution Products, Methods, and Trial Rates

For the first and secondary IBA **(K-IBA)** rooting solution applications use the foliar Spray Drip Down Method®. Use on leafy cuttings in the growing season. When doing multiple applications, for the first rooting solution application only the Total Immerse Method or Basal Quick Dip Method can be substituted.

Rooting Solution Products

- **Hortus IBA Water Soluble Salts®**
- **Rhizopon® AA Water Soluble Tablets**

Dissolve these products in water to make aqueous IBA **(K-IBA)** rooting solutions, for all plants propagated from cuttings. These are the only IBA products labeled for foliar methods.

Basal Quick Dip Method (only used for a first rooting solution application)
The basal ends of the cuttings are dipped about 3/4 inch into the rooting solution then stuck in media. Rates are established per plant variety.
Spray Drip Down Method® (used for first or secondary rooting solution applications)
The cuttings are stuck in media. A skilled worker sprays the rooting solutions onto the leaves until the solution drips down. Spraying is done soon after sticking or when not under heat stress, such as early morning. An excess of solution is best rather than a starved liquid volume. Facility appropriate spray equipment is used such as backpack, hydraulic, booms, or robots.
Total Immerse Method (only used for a first rooting solution application)
The cuttings are totally immersed a few seconds in the rooting solution then stuck in media.

Rooting Solution Trial Rates

Spray Drip Down and Total Immerse Methods (for first time application) trial IBA and rooting solution rates using Hortus IBA Water Soluble Salts. The first foliar and supplementary applications are at the same rate (**IBA ~ K-IBA rates**).

- annuals, perennials, chrysanthemums: 80-250 *ppm* IBA (typical 150-200)
- herbaceous & hard-to-root perennial cuttings: 250-1500 *ppm* IBA (typical 750-1000)
- woody ornamental cuttings: 300-1500 *ppm* IBA (typical 750-1000)

Use Rooting Hormone or Eat Ice Cream?

A vegetative breeder tests whether rooting hormone is really worth using on the most popular varieties.

Kris Carlsson, featuring research from Luís Muñoz

Growing up, I remember reading an article about my favorite baseball player, Rickey Henderson, where it said Rickey ate a gallon of ice cream every night after the ball game. Rickey attributed this gallon of ice cream to making him one of the best base stealers in baseball history. I tried to convince my mom way back when that she should let me eat a gallon of ice cream every night, but no success. What does this have to do with rooting hormone? I think the hormone is like the ice cream for your cuttings—it won't allow them to steal a base faster, but they will root faster.

There are many methods and techniques used to propagate successfully. They can vary from carefully planning and preparing every detail to having a fancy propagation system in place, but can rooting hormone be a contribution to this success? What's the right rooting hormone to use? What technique should I use to apply rooting hormone? Today, we plan to answer this question.

The trials

We set up a trial to evaluate cuttings stuck with no hormone compared to powder dipping of Hormex #1 and #3, liquid dipping in Hortus IBA Quick Dip Solution, and overhead sprays of Hortus IBA at 100 ppm and 200 ppm. All of these applications were made at stick with propagation-difficult crops like osteospermum and lantana. We also did the same treatment to calibrachoa, which many growers do not use rooting hormone on.

Finally, we looked at geraniums under the same treatments. My colleague Luís Muñoz was pulling 10 cuttings every other day to evaluate development as the cuttings callused, initiated roots and rooted to the edge of the Ellepot. In the initial stages before root development, all cuttings were pulled randomly from the tray and dumped after evaluation so that results were not skewed by damaged cuttings stuck back into the Ellepot.

Osteospermum

At approximately five days after stick, Osteo Serenity Pink Magic cuttings had a higher callus initiation percentage when using rooting hormone. Pink Magic cuttings that were stuck into 105 trays with no hormone averaged about 40% callusing at five days after stick, while cuttings that were stuck with no hormone, then treated with an IBA 100 ppm hormone spray right after stick, had an average of 90% callus initiation five days after stick.

This later translated into quicker rooting with the hormone spray application and, two weeks after stick, we noticed a larger difference in rooting (see Figure 1). Hormone use proved to have promoted a better, more developed liner, which ultimately allowed us to pull liners out of mist and propagation about four days sooner than our no-hormone treatment.

Calibrachoa

Calibrachoa is typically a crop we don't use rooting hormone on because it roots fairly well, but we still put it to the test. Calibrachoa Cabaret Deep Yellow at five days after stick with no hormone had an average of 80% of cuttings show some sort of callus. This is really great for a crop that requires no rooting hormone. However, when we compared it to our IBA 100 ppm spray treatment, we noticed a difference. At five days after stick, we had 100% of cuttings showing callus and about 50% of those had small roots beginning to root into the soil. Another detail we noticed was that for the first 10 days, IBA treatments displayed more wilting/leaf curl than our no-hormone treatment.

Approximately two weeks after stick, 90% of cuttings stuck with no hormone began to show some roots emerging out to the edge of the liner, while cuttings that received the hormone application were already developing roots outside of the liner (see Figure 2). They appeared to have at least twice as many roots as our no-hormone treatment. This allowed us to remove the hormone treatment out of mist earlier and out of propagation one week sooner. All signs of wilt from the IBA spray disappeared at 10 days after stick.

Geranium

Hormone use on geraniums is optional. We chose to try our Geranium Dynamo Dark Red and repeated the same treatments. Geraniums that were stuck ▶

Osteo Serenity Pink Magic
No Rooting Hormone

Osteo Serenity Pink Magic
IBA 100 ppm Spray

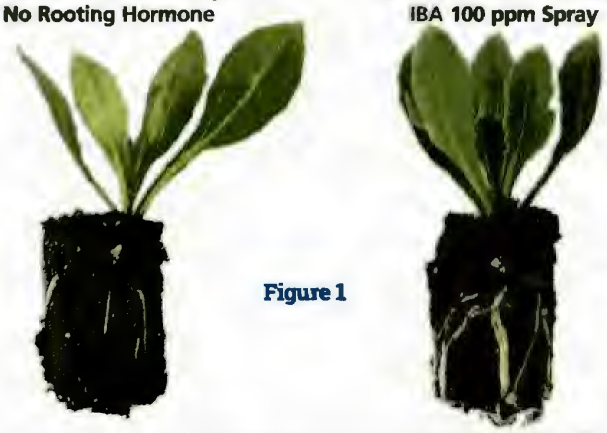


Figure 1

Calibrachoa Cabaret Deep Yellow
No Rooting Hormone

Calibrachoa Cabaret Deep Yellow
IBA 100 ppm Spray

Figure 2

Geranium Dynamo Dark Red
No Rooting Hormone

Geranium Dynamo Dark Red
IBA 100 ppm Spray

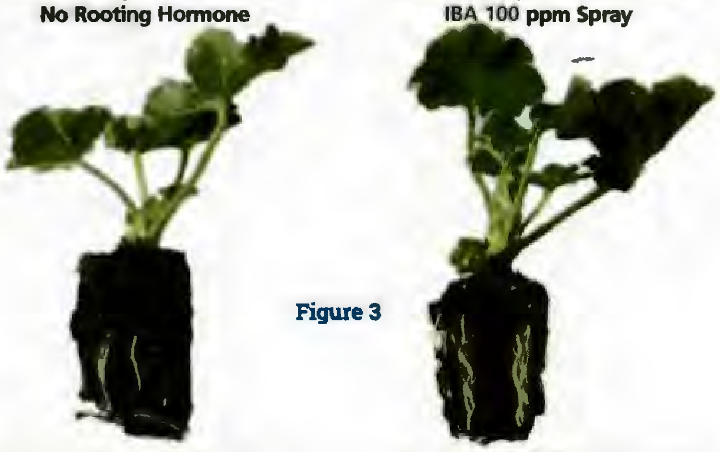


Figure 3

Lantana Landmark Rose Sunrise
No Rooting Hormone

Lantana Landmark Rose Sunrise
IBA 100 ppm Spray

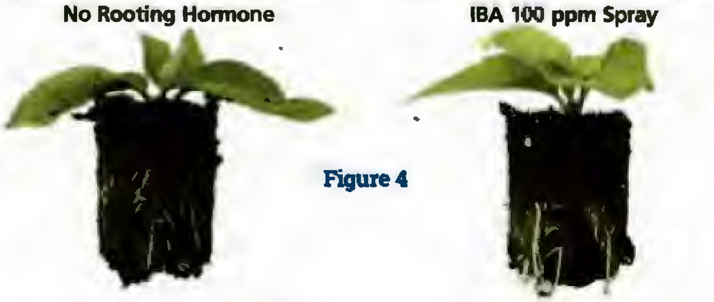


Figure 4

with no hormone only resulted in about 50% of callusing at five days after stick. Whereas geraniums that received an IBA 100 ppm spray after stick had 100% of cuttings begin to callus five days after stick. Once again, IBA application seemed to cause wilting/leaf curl symptoms for about 10 days before they grew out of it.

Two weeks after stick, no-hormone treatment only had about 60% of liners showing minimal rooting and our IBA 100 ppm spray once again provided better results. One hundred percent of liners were more developed and showed a much larger amount of roots (see Figure 3). This allowed us to remove from propagation four days ahead of the no-hormone treatment.

Lantana

Lantana Landmark Sunrise Rose had 100% of cuttings initiate callusing five days after stick with no hormone. (I guess Luís is a really good lantana propagator!) Lantanas that received the IBA 100 ppm spray also showed some advantage. They were all callused as well, but about 40% of them showed some minimal signs of roots beginning to sprout. For lantanas, it took a little longer for differences to show. Two weeks after stick, no-hormone treatment only had about 30% of cuttings achieve very small root growth to the edge of the Ellepot. Our IBA 100 ppm spray was only able to get us to 50%, achieving some growth to the Ellepots as well. Slightly larger roots than our no-hormone treatment, but not enough to make a huge difference.

Lantana Landmark Sunrise Rose stuck with no hormone were finally ready to be moved out of propagation about four weeks after stick. Lantana with IBA 100 ppm spray treatment were ready to be moved out of propagation approximately 25 days after stick, only giving it about a three-day head start compared to the no-hormone treatment. You can see a small difference for liners receiving the IBA 100 ppm spray in the picture taken approximately four weeks after stick (see Figure 4). Is it worth it? Please trial under your propagation conditions to check.

So, in conclusion, if you want to root cuttings as fast as Rickey Henderson steals bases, you should use rooting hormone. I think that you should start a trial today—even on crops that don't require rooting hormone to see if you can root faster, high-quality liners. Our conclusion was that IBA spray at 100 ppm gave the best rooting results while providing the lowest input cost during stick.

Also, please feel free to eat a gallon of ice cream every night. Just keep in mind you better start running fast like Rickey or you're going to feel the extra pounds!

Kris Carlsson is the Global Product Manager and Luís Muñoz is Culture Research Technician for Ball FloraPlant. Both are stationed in Arroyo Grande, California. Please visit ballfloraplant.com for the full presentation of their trials.

Foliar Application of Rooting Hormone

by Brian Decker, Decker's Nursery
Presented at the International Plant Propagator's Eastern Region meeting, September 2016

Who we are:
Decker's Nursery is currently broken down into three separated production areas.
Field: Approximately 90 acres
Deciduous and conifer B&B, bare root liners, and stock blocks for liner production
Container: Approximately 26 acres. Potted shrubs, trees, conifers, perennials, liners, and grasses.
Liner: Approximately 14 acres. Shrubs, grafted and non-grafted conifers, and specialty products.

Field B&B production

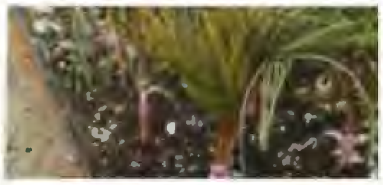
One gallon boxwood

Three gallon grasses

Three gallon shrub production

SEE THE VIDEOS: http://hortus.com/decker.htm

Vanderwolf's pyramid pine grafts

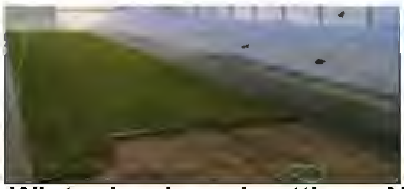


Grafted Fat Albert Spruce

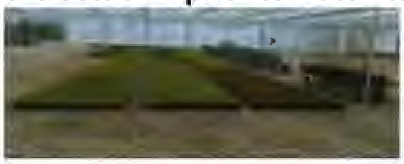
Grafting rhododendron on Inkarho #37 understocks

Jupiter grafts

Softwood cuttings in mist



Winter hardwood cuttings. Note cuttings are setdown prior to Dutch tent installation



Liner production propagation

LTL shipping pallets

Juniper grafts on a rolling cart for delivery

LTL pallet of juniper headed for shipping

Hand dipping cuttings in Hortus IBA Water Soluble Salts rooting solution

Major Presentation Points
> History & evolution of Hortus IBA Water Soluble Salts rooting spray application
> Summary of observations
> Status of future research

Fun with talc

Spilled liquid rooting hormone

Dipping cuttings in liquid hormone

When things go well

When things go south ..
It is fustrating to know why

Obstacles or fears about the
Spray Drip Down Method

- Sprayer application uniformity
- Hormone storage overnight once mixed
- Inaccurate foliar application between spray supervisors
- General resistance to change

The eight most dangerous words in the nursery
“But that is the way we always did it”

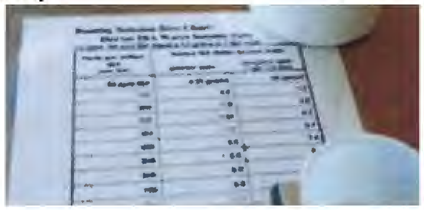
Products used to make IBA Rooting Solutions for use by the foliar Spray Drip Down Method

Rhizopon AA Water Soluble Tablets

Hortus IBA Water Soluble Salts

Dramm Sprayer

Sprayer in action with a fine mist
http://hortus.com/decker.htm



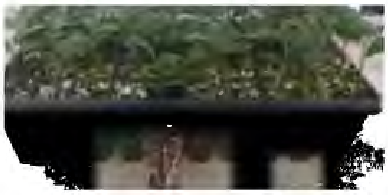
A scale is used to accurately measure Hortus IBA Water Soluble Salts.
Weights per liquid volume are in a table

Over spray by the Spray Drip Down Method using Hortus IBA Water Soluble Salts solutions. A fine mist comes out of the spayer nozzles. Solution spray application is through windows of a tent. You can see videos at http://hortus.com/decker.htm

A winter cutting with good root formation

Rooted Barberry

A high oxygen root system in RootMaker trays. We are always in search of that elusive propagtion tray with good air penetration, water column, root shaping/ development characteristics, and ease of plug removal. COST!



Burning Bush plugs: This is an example of a plant cuttings that requires higher rates of Hortus IBA Water Soluble Salts rooting solutions in the summer

Winter cuttings both in and out of the rooting tent. We fill a side then erect the Dutch style tent. This allows for an easier application of the rooting hormone solution,

Spray Drip Down Method using Hortus IBA Water Soluble Salts IBA rooting Solution
See video at
http://hortus.com/decker.htm

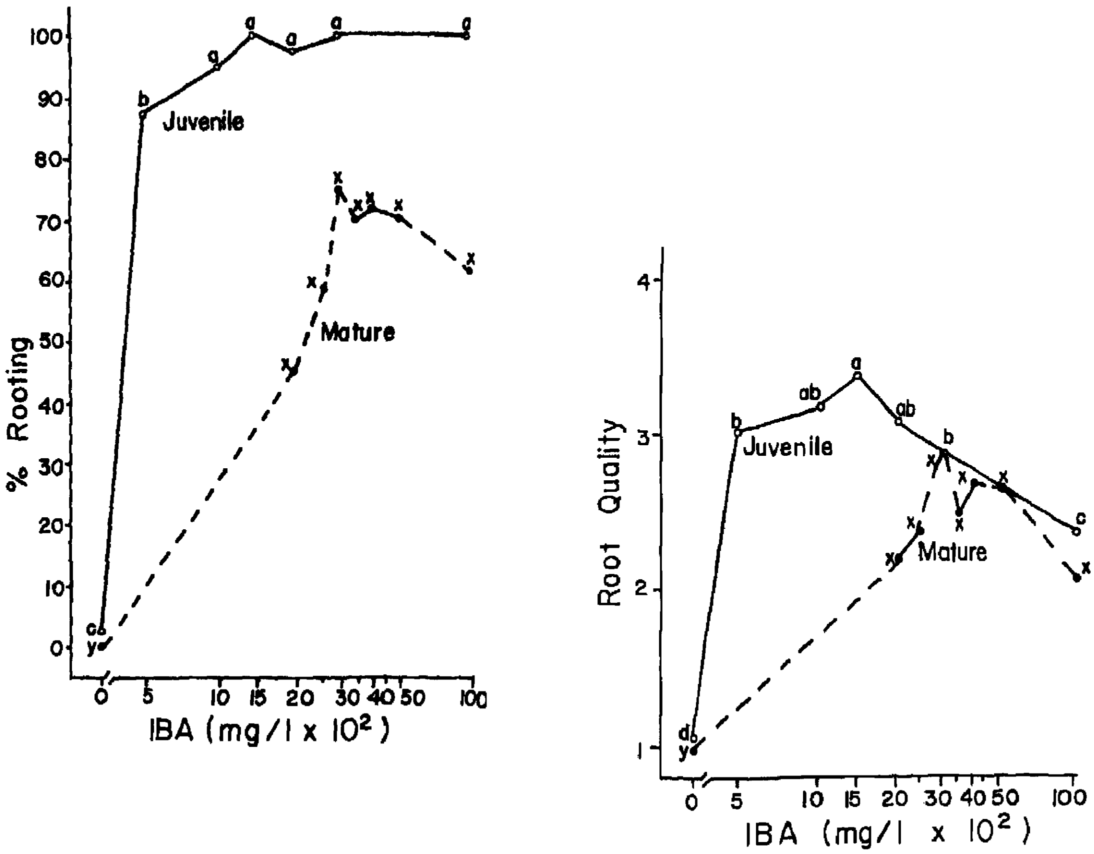
FOLIAR SPRAY DRIP DOWN PROTOCOL FOR APPLICATION USING HORTUS IBA WATER SOLUBLE SALTS ROOTING SOLUTIONS.

- Use distilled water for mixing Hortus IBA Water Soluble Salts (may not be critical)
- Use a flag marker to identify the day sticking progress to identify the three day spray rotation.
- Measure Hortus IBA Water Soluble Salts to mix in one gallon increments. One gallon of water plus 30 grams of Hortus IBA Water Soluble Salts equals close to 1500 ppm IBA
- Unused rooting hormone solution is kept overnight. Add additional rooting hormone solution in gallon increments.
- All foliar rooting hormone solution applications occur early in the morning. Stomata are open and cuttings are generally not in moisture stress.
- Improve root formation during positive trials either when spraying three days in a row after sticking, or spraying at three times weekly after sticking.

QUESTIONS FOR RESEARCH

Are multiple spray rooting hormone applications required or benefitial such as:

- either three days in a row after sticking or three times weekly after sticking?
- what are the most effective ppm IBA rates?
- does the application time of day have an effect?
- in re-application, what is the best interval?
- is the rooting hormone phytotoxic or can cause burn problems?



J. Amer. Soc. Hort. Sci. 105(1):91–95. 1980.

Growth Regulator Effects on Adventitious Root Formation in Leaf Bud Cuttings of Juvenile and Mature *Ficus pumila*[1]

F. T. Davies, Jr.[2] and J. N. Joiner
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Additional index words. indolebutyric acid, 6-(benzylamino)-9-(2-tetrahydropyranyl)-9H-purine, gibberellic acid, creeping fig

Abstract. **Adventitious root formation was stimulated with foliar application of indolebutyric acid (IBA) from 1000 to 1500 mg/liter for juvenile and 2000 to 3000 mg/liter for mature leaf bud cuttings of *Ficus pumila* L. IBA increased cambial activity, root initial formation, and primordia differentiation and elongation. IBA stimulated rooting when applied to juvenile cuttings at 3, 5, or 7 days after experiment initiation, but had no effect on mature cuttings when applied at day 15, the final treatment period. The interaction of IBA/gibberellic acid (GA_3) did not affect early root development stages, but reduced root elongation and quality once primorida had differentiated. IBA/6-(benzylamino)-9-(2-tetrahydropyranyl)-9H-purine (PBA) inhibited rooting at early initiation stages.**

Recent researchers have generally agreed that adventitious root formation (ARF) involve sequences of histological steps with each step having different requirements for growth substances (5, 8, 9, 10, 11). Eriksen (5) and Mohammed and Eriksen (8) found that auxins and cytokinins had different affects on ARF depending on developmental stage. Sircar (11) reported 5 different histological stages in which GA_3 and IAA alternately promoted or inhibited ARF. Hypocotyl cuttings of herbaceous annuals have been used in previous sequencing

[1] Received for publication April 9, 1979. Florida Agricultural Experiment Station Journal Series No. 1731.

The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper must therefore be hereby marked *advertisement* solely to indicate this fact.

[2] Present address: Horticultural Science Department, Texas A&M University, College Station, TX 77843.

experiments, but herbaceous material may not give a true index of changes occurring in mature woody materials.

The woody ornamental creeping fig *(Ficus pumila)* exhibits strong dimorphism (2) and differences in rooting between the juvenile and mature forms. Objectives of this study were to determine the effect of IBA, PBA, and GA_3 applied at different rooting developmental stages to juvenile and mature leaf-bud cuttings (LBC) of *F. pumila*.

Materials and Methods

F. pumila cultivated on the University of Florida campus at Gainesville were used as stock plants. Leaf bud cuttings (LBC-lamina, petiole and 2.5 cm piece of stem with attached axillary bud) were rooted under an intermittent mist system in a medium of sterilized mason sand maintained at 24°C with a 2 hr night light interruption previously described (4). Juvenile LBC were harvested after 21 days and mature cuttings 42 days after experiments were initiated. All growth regulators were applied as aqueous sprays with 0.25 ml/liter of surfactant, emulsifiable A-C polyethylene and octyl phenoxy polyethoxy ethanol (Plyac).

In an experiment to establish optimum IBA concentration required for rooting, cuttings were taken in November and IBA applied at 500, 1000, 1500, 2000, 3000, and 10,000 mg/liter to juvenile and 2000, 2500, 3000, 4000, 5000, and 10,000 mg/liter to mature LBC at time of insertion. The design was a randomized complete block with 4 replications and 40 cuttings per treatment.

To characterize growth regulator effects at different root development stages a factorial experiment was initiated in May with 2 forms (juvenile, mature LBC) × 2 IBA pretreatments (control, treated) × 3 growth regulators (IBA, PBA, GA_3) × 3 application dates. An IBA spray of 1000 mg/liter was applied to half the juvenile cuttings and 3000 mg/liter to half the mature material at the time of insertion. Growth regulators were then applied after 3, 5, or 7 days for juvenile and 3, 9 or 15 days for mature cuttings: IBA at 1000 mg/liter for juvenile and 3000 mg/liter for mature cuttings, 1000 mg/liter PBA and 3000 mg/liter GA_3 for both types. The design was a randomized complete block with 4 replications and 32 cuttings per treatment. To determine stage of ARF 10 cuttings of each treatment combination were selected at each of the 3 time intervals and fixed in formalin-acetic acid-ethanol (FAA) *in vacuo*, dehydrated in ethanol-tertiary butyl alcohol series and embedded in Paraplast-plus. Blocks containing stem pieces with one surface exposed were soaked in distilled water *in vacuo* for 5 days to soften tissues prior to sectioning. Serial cross and longitudinal sections were cut at 8 and 11 um and strained with safranin and fast green.

Cuttings were measured for percent rooting, root number, and root length (average of 3 longest roots) and rated on a quality scale of 1 to 4 with 1 = no rooting, 2 = small root system, 3 = intermediate root system and 4 = extensive root system.

Results

Optimum IBA concentration. IBA treatments stimulated ARF in both juvenile and mature LBC (Fig. 1, 2, 3, 4). At high IBA levels root length was reduced in both forms (Fig. 3) and root quality in juvenile cuttings was poor (Fig. 4). Best horticultural responses were obtained in juvenile material treated with 1000-1500 mg/liter and mature cuttings treated with 2000-3000 mg/liter IBA considering root number, length and quality (Fig. 2, 3, 4). The performance of IBA-treated juvenile LBC was better than IBA-treated mature cuttings.

Hormonal effects during rooting stages. Percent rooting in IBA pretreated cuttings was unaffected by additional IBA at any of the 3 time intervals after insertion, however, root length was reduced in all treatments (Table 1, 2). In juvenile LBC receiving no IBA pretreatment, later IBA application increased rooting in all dates (Table 1), but in mature cuttings only the first or second application period was stimulatory (Table 2).

GA_3 reduced root length and quality in IBA-pretreated cuttings (Table 1, 2 and Fig. 5, 6). In juvenile cuttings without IBA pretreatment, GA_3 reduced root length (Table 1), but had no effect on mature LBC without IBA pretreatment (Table 2).

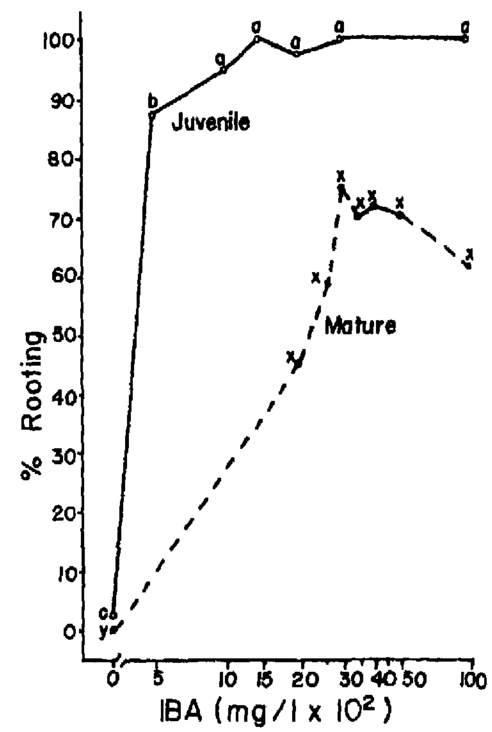

Fig. 1. Effect of IBA on rooting in juvenile and mature leaf bud cuttings of *Ficus pumila*. Points with same lower case letters are not significantly different.

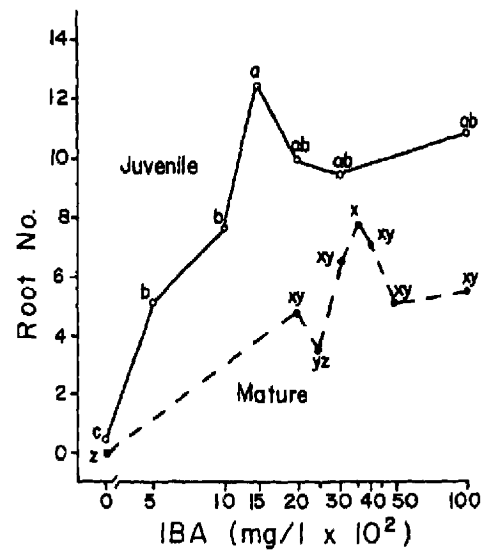

Fig. 2. Effect of IBA on root number in juvenile and mature leaf bud cuttings of *Ficus pumila*. Points with same lower case letters are not significantly different.

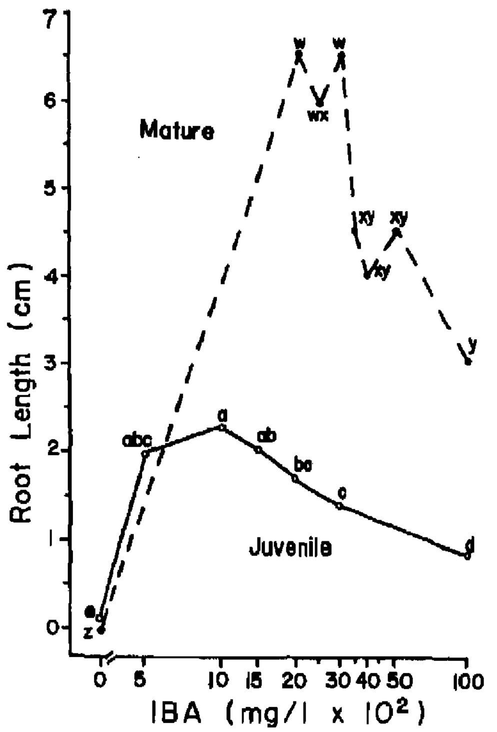

Fig. 3. Effect of IBA on root length in juvenile and mature leaf bud cuttings on *Ficus pumila*. Points with same lower case letters are not significantly different.

Table 1. Adventitious root formation in juvenile leaf bud cuttings of *Ficus pumila* treated with 3 growth regulators at 3, 5, or 7 days after experiment initiation. Half the cuttings were pretreated with 1000 mg/liter IBA.

IBA pre-treatment (mg/liter)	Growth regulator post treatment	Rooting (%)	No. roots	Root length (cm)	Root quality scale[z]
0	IBA				
	(1000 mg/liter)				
	day 3	100a[z]	9.5e	1.1bcde	2.6de
	day 5	100a	11.0bcde	1.1bcde	2.8cd
	day 7	100a	10.3cde	1.0bcde	2.5de
	GA_3				
	(3000 mg/liter)				
	day 3	31c	0.7h	0.8cde	1.3gh
	day 5	28c	0.8h	0.7de	1.3gh
	day 7	34c	1.0h	1.5bcd	1.5g
	PBA				
	(1000 mg/liter)				
	day 3	0d	0h	0h	1.0h
	day 5	25c	0.9h	1.2bcde	1.3gh
	day 7	25c	0.9h	1.4bcd	1.3gh
	Control	31c	0.8h	1.7b	1.3gh
1000	IBA				
	(1000 mg/liter)				
	day 3	100a	12.7b	1.5bc	3.0abc
	day 5	100a	15.2a	1.3bcd	3.2ab
	day 7	100a	12.4bc	1.0bcde	2.7cd
	GA_3				
	(3000 mg/liter)				
	day 3	100a	10.8bcd	1.3bc	2.7cde
	day 5	100a	9.0ef	1.5bc	2.8cd
	day 7	100a	10.2de	1.7b	2.8bcd
	PBA				
	(1000 mg/liter)				
	day 3	38c	1.3h	0.5ef	1.4gh
	day 5	66b	5.3g	1.3cde	2.0f
	day 7	88a	7.2fg	1.2bcde-	2.3ef
	Control	100a	11.9bcd	2.5a	3.4a

[z]Root quality scale range from 1 to 4 with 1 = no root system, 2 = small root system, 3 = intermediate root system and 4 = extensive root system.
[y]Mean separation in columns by Duncan's multiple range test, 5% level.

PBA effectively limited ARF in IBA-pretreated cuttings when applied during the first or second time intervals (Tables 1, 2). In juvenile LBC the greatest inhibition occurred during the first time interval which coincided with increased cambial activity associated with the dedifferentiation phase of ARF (Table 3). PBA caused less inhibition of ARF the second application period when root initials and primordia were first observed. Half the LBC rooted by the third interval (Table 3); thus PBA application at this time did not affect % rooting but did reduce root number, length and quality. In mature cuttings PBA treatment at first application period completely inhibited ARF (Table 2) when no cambial activity was observed. PBA was less effective in inhibiting ARF during second application when cambial activity was first observed (Table 2, 4). Root length and quality were reduced with PBA application at any period, but had no effect on % rooting or number during the third treatment period.

PBA reduced rooting in juvenile cuttings not pretreated with IBA when applied during the first treatment period when neither root initials nor primordia were observed (Table 1, 3). In mature cuttings PBA had no statistical effect on rooting; however, none of the treated cuttings formed roots, nor were root initials or primordia observed (Table 2, 4).

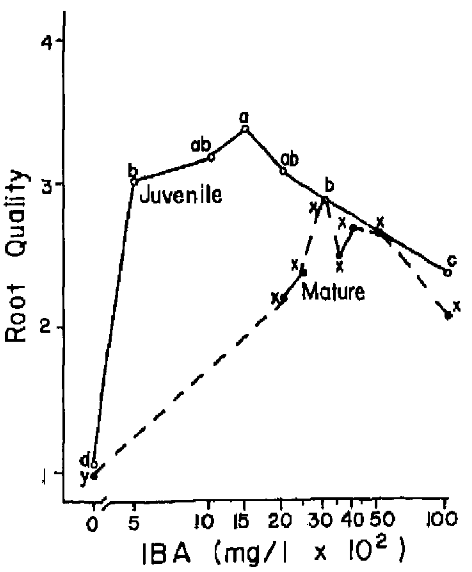

Fig. 4. Effect of IBA on root quality in juvenile and mature leaf bud cuttings of *Ficus pumila*. Points with same lower case numbers are not significantly different.

Discussion

Mature *F. pumila* cuttings did not root as efficiently as juvenile material. Thus, IBA-treated mature cuttings required higher exogenous auxin levels and longer time to obtain

Table 2. Adventitious root formation in mature leaf bud cuttings of *Ficus pumila* treated with 3 growth regulators at 3, 9, or 15 days after experiment initiation. Half the cuttings were pretreated with 3000 mg/liter IBA.

IBA pre-treatment (mg/liter)	Growth regulator post-treatment	Rooting (%)	No. roots	Root length (cm)	Root quality scale[z]
0	IBA				
	(3000 mg/liter)				
	day 3	84abc[z]	13.1abc	3.4ab	3.0ab
	day 9	94ab	8.6cde	3.0ab	2.7abc
	day 15	53cdefg	2.7fg	1.0cde	1.7efg
	GA_3				
	(3000 mg/liter)				
	day 3	44efg	2.0fg	0.7de	1.5fgh
	day 9	41fg	1.9fg	0.8cde	1.5fgh
	day 15	38fg	1.1fg	0.8cde	1.4gh
	PBA				
	(1000 mg/liter)				
	day 3	0h	0g	0e	1.0h
	day 9	0h	0g	0e	1.0h
	day 15	0h	0g	0e	1.0h
	Control	22gh	1.5fg	1.1cde	1.3gh
3000	IBA				
	(3000 mg/liter)				
	day 3	81abcd[z]	11.1bcd	2.1bcd	2.6bcd
	day 9	100a	16.1a	3.1ab	3.2ab
	day 15	91ab	13.7ab	2.1bcd	2.7abc
	GA_3				
	(3000 mg/liter)				
	day 3	66bcdef	8.4cde	1.6cd	2.0def
	day 9	50defg	6.0ef	1.7cd	1.8efg
	day 15	66bcdef	7.3de	2.2bc	2.1cde
	PBA				
	(1000 mg/liter)				
	day 3	0h	0e	0e	1.0h
	day 9	28gh	1.6fg	1.0cde	1.3h
	day 15	75abcde	9.2bcde	1.3cde	2.2cde
	Control	94ab	13.3abc	3.8a	3.2a

[z]Root quality scale ranged from 1 to 4 with 1 = no root system, 2 = small root system, 3 = intermediate root system and 4 = extensive root system.

[y]Mean separation in columns by Duncan's multiple range test, 5% level.

maximum rooting (3) than juvenile LBC. Mature cuttings may have lower endogenous auxin levels and/or other endogenous chemicals needed to stimulate root initiation. When ARF was measured on a daily basis (3), IBA-treated mature cuttings rooted slower than juvenile LBC, but equalled juvenile controls by day 20, giving strong evidence that endogenous auxin levels were acting as a possible limiting factor in root initiation.

IBA increased ARF in both juvenile and mature cuttings by stimulating initiation of cambial activity, root initials and primordia, which agrees with reports that auxins trigger early formation of root primordia (6). However in *F. pumila*, application of auxin above the optimum level reduced root length and quality indicating that primordia elongation was decreased.

In both juvenile and mature cuttings the combination of IBA/GA_3 retarded rooting after primorida were differentiated, since % rooting was not influenced but root length and quality were reduced. The conflicting reports on exogenous gibberellin influence on rooting (1, 7, 12) may be related to species differences. Our results agree with Hassig (7) who reported that initiating primordia were least affected by GA_3 but that cell number was reduced in older established primordia which was deleterious to root formation.

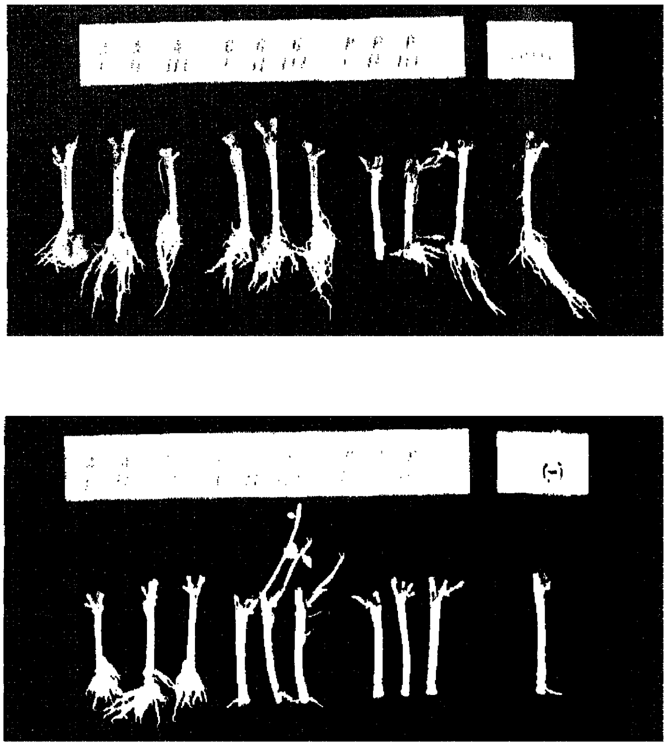

Fig. 5. Effect of IBA, GA_3 and PBA on adventitious root formation when applied at 3 time intervals to juvenile leaf bud cuttings. (top) Pretreated with (IBA). (bottom) No pretreatment with IBA.

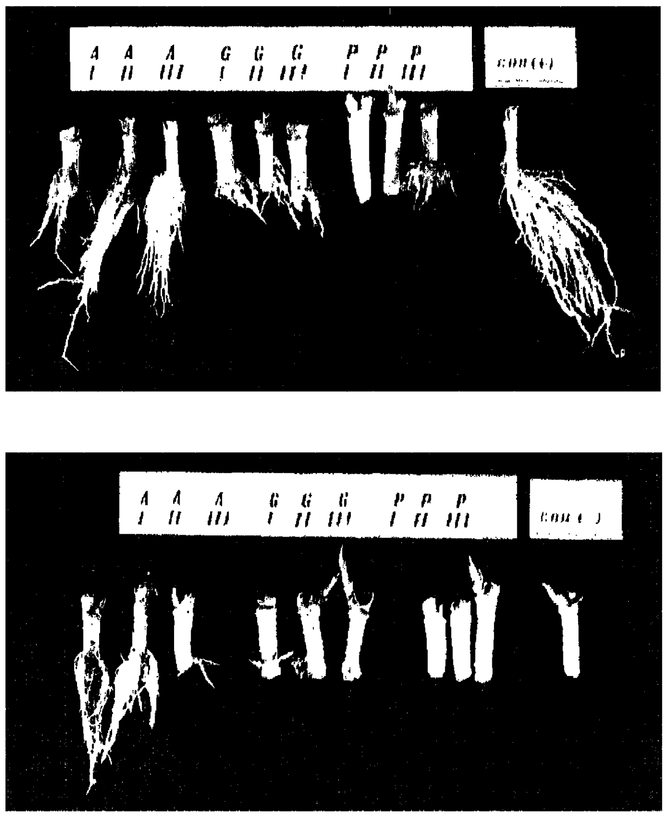

Fig. 6. Effect of IBA, GA_3 and PBA on adventitious root formation when applied at 3 time intervals to mature leaf bud cuttings. (top) Pretreated with IBA. (bottom) No pretreatment with IBA.

Table 3. Stage of adventitious root formation of juvenile leaf bud cuttings of *Ficus pumila* at 3 time intervals.

Treatment	Increased cambial activity	Root initials	Root primordia	Rooting (%)	No. roots	Root length (cm)	Root quality scale[z]
IBA pretreatment at (1000 mg/liter)							
day 3	yes	none	none	0	0	0	1.0
day 5	yes	yes	yes	0	0	0	1.0
day 7	yes	yes	yes	50	6.2	0.7	1.6
No IBA pretreatment							
day 3	none	none	none	0	0	0	1.0
day 5	yes	none	none	0	0	0	1.0
day 7	yes	yes	yes	20	0.4	0.5	1.2

[z]Root quality scale ranged from 1 to 4 with 1 = no root system, 2 = poor root system, 3 = intermediate root system and 4 = extensive root system.

Table 4. Stage of adventitious root formation of mature leaf bud cuttings of *Ficus pumila* at 3 time intervals.

Treatment	Increased cambial activity	Root initials	Root primordia	Rooting (%)	No. roots	Root length (cm)	Root quality scale[z]
IBA pretreatment at (3000 mg/liter)							
day 3	none	none	none	0	0	0	1.0
day 9	yes	none	none	0	0	0	1.0
day 15	yes	yes	yes	20	1.7	0.5	1.2
No IBA pretreatment							
day 3	none	none	none	0	0	0	1.0
day 5	none	none	none	0	0	0	1.0
day 15	yes	none	none	0	0	0	1.0

[z]Root quality scale ranged from 1 to 4 with 1 = no root system, 2 = poor root system, 3 = intermediate root system and 4 = extensive root system.

The rooting inhibition of PBA on juvenile and mature *F. pumila* concur with reports that cytokinins inhibit preinduction phases of rooting (12) with a loss of inhibitory effect at later stages (6).

Differences in adventitious rooting between juvenile and mature cuttings may be partially attributed to endogenous auxin levels, since lower IBA levels were required for optimal rooting in juvenile compared to mature LBC. However, other factors such as auxin/cytokinin and auxin/GA_3 ratios, cofactors and inhibitors may be involved, since exogenous IBA applications did not overcome root formation differences between IBA-pretreated juvenile vs. mature tissue.

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Osteospermum var "sweet yellow"
Photos taken 21 days after foliar application of
Hortus IBA Water Soluble Salts rooting soluition

Treatments (ppm IBA as Hortus IBA Water Soluble Salts):
control (no treatment)
200 ppm IBA, 1 treatment > 1 day after sticking
400 ppm IBA "
600 ppm IBA "
1200 ppm IBA "
200 ppm IBA, 2 treatments > 1 day after sticking and 10 days after sticking
400 ppm IBA "
600 ppm IBA "
1200 ppm IBA "

Control (no treatment)

200 ppm IBA (one treatment)


400 ppm IBA (one treatment)


200 ppm IBA (two treatments)


400 ppm IBA (two treatments)

600 ppm IBA (one treatment)


1600 ppm IBA (one treatment)

600 ppm IBA (two treatments)


1600 ppm IBA (two treatments)

One Treatment

Two Treatments

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